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Environmental Effects of Dredging

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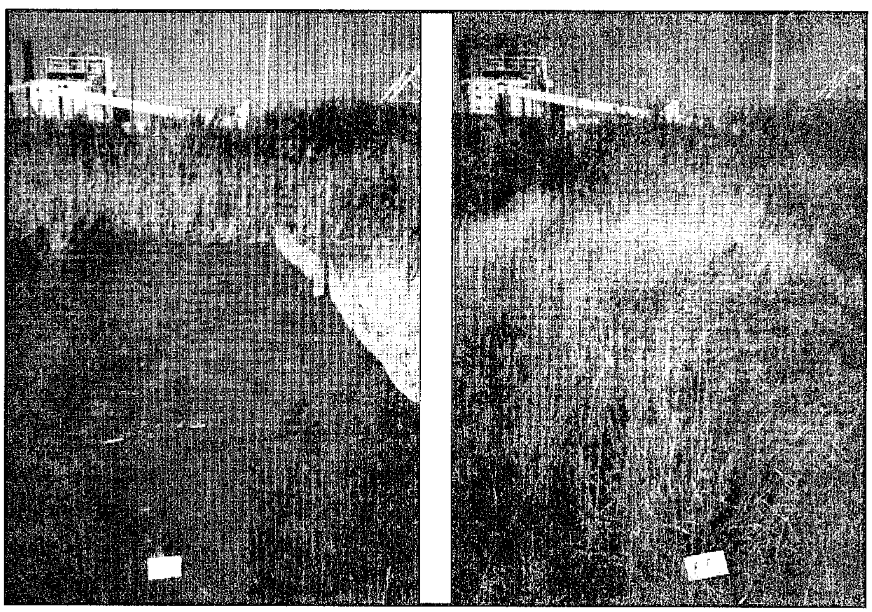
Update: Evaluating ecosystem development at contaminated dredged material placement sites

by Dennis L. Brandon, Charles R. Lee, and John W. Simmers

Contaminated sediment dredged from Black Rock Harbor, Connecticut, was placed in aquatic, upland, and wetland environments as part of the Field Verification Program (FVP), a 6-year joint effort of the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency (Peddicord 1988).

Scientists at the U.S. Army Engineer Waterways Experiment Station (WES) conducted laboratory experiments on the sediment prior to dredging, to evaluate the potential contaminant mobility for each dredged material disposal alternative. In October 1983, WES began evaluating the colonization of plants and animals into the upland and wetland sites and the contaminant mobility of heavy metals. Results of the monitoring conducted between 1983 and 1989 were published in an earlier article (Brandon, Lee, and Simmers 1992).

This article examines the colonization and contaminant mobility between 1989 and 1992. It is anticipated that ecosystem development at this site will be evaluated through September 1998.



Black Rock Harbor dredged material (unamended) upland site (left) was barren of vegetation after repeated attempts to introduce suitable plant species. Best growth was later obtained on plots amended with lime, manure, sand, and gravel (right)

Upland environment

The Black Rock Harbor dredged material contained a number of heavy metals at elevated concentrations (Table 1).

Disposal of this material in an upland environment resulted in some pronounced changes. For example, the salinity, pH, and organic matter decreased (Table 2).

Table 1
Characterization of Black Rock Harbor Dredged Material

Parameter	Content[1]
Zinc	1,307.1
Cadmium	22.4
Copper	2,728.4
Nickel	178.8
Chromium	1,651.0
Lead	397.8
Mercury	2.0
Arsenic	22.9
Iron	31,000.0
Oil and grease	17,452.4
Chemical oxygen demand	232,880.0
Total organic carbon	54,104.0
Percent organic matter	19.8
Percent calcium carbonate equivalent	1.0
Percent total sulfur	1.3
Wet sediment pH	7.6
Dry sediment pH	6.6
Percent sand	42.0
Percent silt	47.0
Percent clay	11.0
Salinity, parts per thousand	28

[1] Contaminant concentrations are expressed in micrograms per gram (dry weight) unless noted otherwise.

The substantial decrease in soil pH enhanced the solubility and availability of the toxic metals zinc, cadmium, copper, nickel, chromium, and lead.

Surface-applied soil amendments of lime, manure, and sand, plus limestone gravel, were used to stabilize the dredged material, control erosion, and alter the dredged material for plant and animal colonization. These soil amendments were selected to counteract the extensive chemical and physical changes that occurred when Black Rock Harbor dredged material dried and oxidized.

Upland plants

Field plots were seeded with redtop (*Agrostis alba*), red fescue (*Festuca rubra*), bluegrass (*Poa compressa*), and several other acid-, salt-, or metal-tolerant species (Brandon and others 1991). After repeated attempts to introduce plant species, the control plots of unamended dredged material were barren of vegetation from 1985 through 1989. From 1989 to 1992, minimal vegetation was established on the amended plots. The best vegetative establishment was observed on the lime + manure + sand + gravel (LMSG) amended plots.

Apparently, the sand and gravel cover allowed rainfall to soak the surface-applied lime and manure into the surface of the dredged material, enhancing plant growth and establishment.

Lee and others (1991) compiled plant tissue information from a number of sources to indicate the potential effects of contaminants on plants. Using these data as guidance, the concentrations of zinc, cadmium, nickel, lead, chromium, and copper in redtop tissue are equal to or above the normal range found in agricultural crops. The only reference tissue concentration that was available for mercury was 1.0 microgram per gram in wheat kernels (as an action level for human foodstuff) (Lee and others 1991). Mercury concentrations in redtop tissue from the upland site and

Table 2
Changes in Soil Conditions After Upland Disposal of Unamended and Amended Contaminated Estuarine Dredged Material

	Control Plots									
	Unamended					Amended[1]				
Parameter	10/83	11/85	6/86	10/89	9/91	10/83	11/85	6/86	10/89	9/91
Soil pH	7.6	3.2	3.2	3.4	4.2	7.6	NS[2]	NS	4.4	4.2
Salinity (parts per thousand)	28	29	13	<1	NS	28	29	13	<2	NS
Percent organic matter	19.5	NS	NS	7.7	7.6	19.5	19.5	NS	8.5	7.4

[1] Lime, manure, sand, and gravel were added to stabilize the dredged material.
[2] No sample.

from a local reference area have exceeded this action level.

The zinc, cadmium, and copper concentrations in redtop tissues appeared to have increased in plants grown on the lime-only plots from 1988 to 1991 (Table 3). This may have been a reflection of the lime amendment losing its effect on metal immobility. The cadmium and copper concentrations in redtop onsite were an order of magnitude higher than in the redtop collected from reference sites in the area.

The reverse trend appeared to occur in redtop grown on the LMSG plots. Concentrations of zinc, cadmium, copper, nickel, and chromium decreased from 1988 to 1991. Lead and mercury tissue concentrations in redtop appeared to be slightly above or below the values observed in the reference sites.

Upland animals

Earthworms placed in this environment during the FVP were not able to survive. Presently, control plots that are void of vegetation continue to contain few animals. No soft-bodied animals were observed or collected from these plots before 1989. Those animals that were collected or observed were transient, foraging species.

In contrast, vegetative growth on the amended dredged material has enhanced the abundance and diversity of animals. Numerous species of macroinvertebrates are associated with the plant cover and the leaf litter layer of the soil.

In October 1991, animals were collected and submitted for chemical analyses (Table 4). The larger amounts of biomass that were collected were identified as crickets (Orthoptera), springtails (Collembola), and slugs/snails (Gastropoda).

Additional sampling would be needed to make comparisons among treatment plots. However, preliminary conclusions from these data indicate that all collected animals had lead concentrations of 10 micrograms per gram or more. The Food and Drug Administration in this country does not have an action level for lead in animal feed or nonspecific food, but FDA-type values have been established in other countries. A value of 10 micrograms per gram has been set by the Dutch for animal feed, and in Australia, a value of 15 micrograms per gram was established for nonspecific food. Since animal lead concentrations appear to be of concern, continued evaluation of lead concentrations in animals should be conducted.

The cadmium concentration of the dredged material was approximately 22 micrograms per gram, with approximately 71 micrograms per gram in slugs. It appears that slugs are accumulating as much as three times the cadmium of the media in which the exposure occurred. Therefore, upland animal accumulation of cadmium is a potential concern and should be evaluated further. Beetles, house mice, birds, and other animals are using the site for feeding and cover.

Surface runoff quality

In August 1991, WES scientists examined surface runoff water quality at the FVP upland disposal site. Experiments were conducted on previously established plots, using the mobile WES Rainfall Simulator to quantify the nature and extent of contaminants in storm-induced surface runoff.

Considerable variability was observed in surface runoff samples from the replicate plots. These plots, which had been established in 1984, had been allowed to develop without interference. Over

Table 3
Average Tissue Contaminant Contents of *Agrostis alba* Plants Growing on the FVP Upland Disposal Site

Contaminant[1]	Normal[2]	1988 Amended-Lime	1989 Amended-Lime	1991		
				Amended-Lime	Reference[3]	Control
Zinc	15-150	85.4	138.7	227.9	386.4	157.9
Cadmium	0.1-1	1.1	1.5	3.1	0.1	1.3
Copper	3-20	15.0	92.2	136.6	11.4	144.3
Nickel	0.1-5	13.4	11.9	14.0	5.4	12.7
Chromium	0.1-1	6.7	26.5	8.7	0.0	28.9
Lead	2-7	3.1	6.2	4.1	10.4	10.4
Mercury	—	0.1	0.1	1.0	4.4	0

[1] All concentrations are expressed in micrograms per gram dry weight.
[2] Lee and others (1991).
[3] Upland areas, Bridgeport, Connecticut.

Table 4
Mean Tissue Contaminant Contents of Animals Colonizing Estuarine Dredged Material Placed in an Upland Disposal Site, October 1991[1]

Contaminant	Control	Treatment[2]			
		Lime	LM	LMSG	LSG
Springtails[3]					
Zinc	127.8	451.6	191.5	609.7	149.6
Copper	67.0	143.6	144.6	108.0	79.4
Nickel	95.3	45.6	26.9	58.4	1,244.7
Cadmium	2.3	4.3	2.7	14.2	5.9
Chromium	12.9	37.5	37.8	17.0	11.3
Lead	—	52.8	12.6	18.4	—
Slugs and Snails[4]					
Zinc	1,739.8	1,274.4	1,742.8	1,260.6	1,896.9
Copper	741.1	277.6	292.3	1,187.5	377.0
Nickel	25.2	32.1	14.8	61.1	10.6
Cadmium	49.9	57.6	40.9	24.6	71.2
Chromium	89.5	70.5	98.5	518.1	32.8
Lead	40.0	19.9	43.0	162.4	14.0

[1] All concentrations are expressed in micrograms per gram dry weight.
[2] Treatments were as follows: LM = lime/manure; LMSG = lime/manure/sand/gravel; LSG = lime/sand/gravel.
[3] Insecta, Order Collembola.
[4] Mollusca, Class Gastropoda.

time, the plots had become much more variable, depending on their position within the disposal site. Statistical differences in the surface runoff results from plots with different treatments were therefore infrequent.

Concentrations of copper and zinc in the unfiltered surface runoff samples from the control plots, from the lime, sand, and gravel (LSG) plots, and from the LMSG plots were statistically greater than the U.S. Environmental Protection Agency (USEPA) Acute Water Quality for Marine Environments. Concentrations of copper and zinc in filtered samples from control plots and LSG plots were statistically greater than the USEPA Acute Water Quality criteria. Concentrations of all heavy metals in filtered samples from LMSG plots were not statistically greater than the criteria.

Concentrations of polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) in surface runoff samples were generally less than the detection limits, with only one filtered sample from as LSG plot containing 0.02 milligram per liter of PCB 1254.

Groundwater samples

Groundwater samples were collected at several sites before the FVP was begun and throughout the life of the project, including December 1989 (month 89 after construction of the upland site) and during 1992 (months 111 and 112 after construction). In groundwater samples collected in December 1989 and October 1992, only metals (arsenic, cadmium, chromium, copper, lead, nickel, zinc, and mercury) were detected. PCBs and PAHs were not detected.

Concentrations of lead (in one well), manganese, and iron in water samples collected in 1989 and 1992 exceeded the state water quality standards. However, these wells also exceeded the standards before the FVP was initiated. In fact, initial groundwater samples showed that concentrations of arsenic, cadmium, chromium, lead, iron, and manganese exceeded the state criteria in three wells. The results of continued groundwater monitoring have indicated that groundwater quality has improved since the site was established.

Wetland environment

Wetland plants

Creation of a salt marsh wetland with Black Rock Harbor sediment

has been successful. One half of the FVP-created wetland was planted with spartina (*Spartina alterniflora*) supplied by Environmental Concern of St. Michaels, Maryland (Figure 1). The other half of the wetland was planted with native spartina collected prior to construction of the dredged material created wetland.

Growth of the Environmental Concern's transplants was slow until 1986 (Table 5). However, beginning in 1987, the spartina gradually expanded to a dense stand that covered the entire side (Brandon and others 1991). Biomass production from both sources was approximately equal in 1991 and 1992.

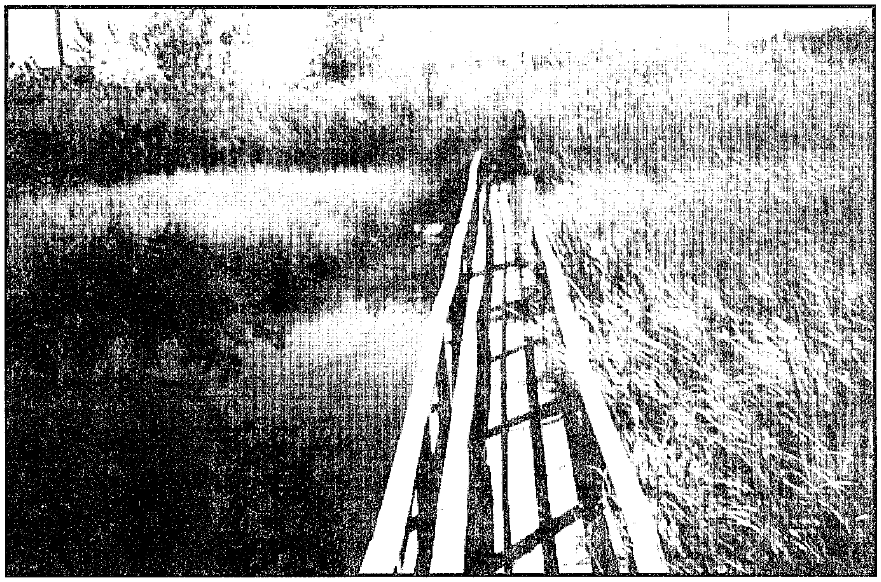


Figure 1. Wetland constructed with Black Rock Harbor dredged material. (Left side planted with native spartina; right side, with spartina obtained from Environmental Concern)

Table 5
Biomass Production of Spartina Grown in Wetland Created with Black Rock Harbor Dredged Material

Transplant Type	Biomass of *Spartina alterniflora* (grams per square meter)					
	1986	1987	1988	1989	1991	1992
Acquired	511	798	226	297	293	525
Native	311	535	337	468	268	548

Note: Natural biomass production value is 627 grams per square meter.

By 1992, the native spartina had not covered its half of the created wetland as completely as the Environmental Concern's transplants.

Both spartina populations trapped sediment carried by the tide and thus increased the elevation of the vegetated wetland. Eventually, the spartina may be replaced by more upland species. Biomass yields in the created wetland have remained in the range of naturally occurring salt marshes in the northeastern United States.

Contaminant concentrations of plant tissue in the created salt marsh were quite similar to those measured in the naturally occurring spartina at Tongue Point prior to wetland creation, and those measured in other naturally occurring salt marshes in the surrounding areas. The possible exception is tissue concentrations of copper.

Tissue concentrations of PAHs, pesticides, and PCBs were relatively low or below detection limits and should not be of concern in the wetland plants studied.

Wetland animals

Snails were marked and introduced into the wetland in 1984. The dredged material was not acutely toxic to the snails, and marked snails were recaptured up to several months later. Native sandworms (*Nereis succinea*) colonized the wetland in 1986. Since that time, fish, crabs, and snails have been observed in the FVP-created wetland.

The wetland has progressed from an open, intertidal mudflat to a spartina marsh with relatively thick vegetation. The animal species have become more diverse and also more difficult to find and quantify, because of the increased vegetative cover. The wetland is used for feeding and resting by several waterfowl species, including the great blue heron and the black-crowned night heron.

Snails (*Ilyanassa* (=*Nassarius*) *obsoleta*) were collected in 1988, 1989, and 1992 and have been

analyzed for contaminant contents (Table 6). The 1988 and 1989 copper, cadmium, and mercury concentrations were less than the respective concentrations of snails collected prior to construction. The 1992 copper and cadmium concentrations were also less than the respective concentrations of snails collected prior to construction. Snail tissue copper, cadmium, and zinc contents appear to be approximately the same in 1992 samples of the field site and the nearby reference site at seaside park.

Snails typically contain elevated levels of copper, possibly due to the high copper concentration in the respiratory pigment (haemocyanin). Food webs based on snails may prove to be at risk from copper, even in naturally occurring ecosystems.

The snail tissue concentrations of nickel, chromium, and lead were slightly elevated over the nearby reference site at seaside park.

Summary

In both the upland disposal and wetland creation field sites, functioning ecosystems with biotic components have developed.

Three areas of potential concern with regard to contaminant mobility are being monitored: the contamination of food webs associated with the upland environment, heavy metal contamination of surface runoff, and heavy metal contamination in wetland animals.

If unanticipated routes of contaminant mobility develop, it is possible that management procedures will be required. WES scientists will continue their monitoring and evaluation activities to better define the nature and long-term extent of contaminant mobility into plants, animals, surface water, and groundwater at the Black Rock Harbor FVP site.

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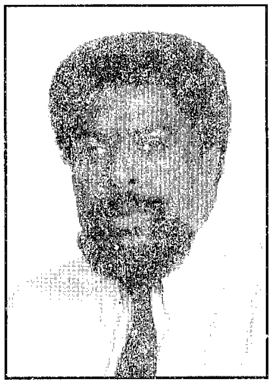
Table 6
Tissue Contaminant Contents[1] of Snails Exposed to Black Rock Harbor Sediments

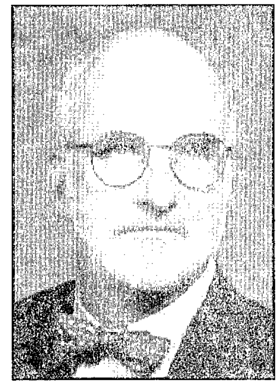
Contaminant	Prior[2]	1988	1989	1992	1992[3]
Zinc	—	878.18	675.2	369.6	352.9
Copper	3,762	1,335.68	1,881.7	1,196.5	1,060.8
Cadmium	11.2	2.93	3.6	3.3	4.4
Nickel	—	8.79	13.3	47.3	7.3
Chromium	—	9.02	29.7	19.6	4.5
Lead	—	10.21	16.1	20.4	12.7
Mercury	0.22	0.08	0.1	—	—

[1] Concentrations are expressed in micrograms per gram (dry weight).
[2] Simmers and others (1989).
[3] Seaside park (reference).



Dennis L. Brandon *is a statistician in the Environmental Laboratory, Waterways Experiment Station. He provides sampling plans, experimental designs, and data analyses for ecological assessments. Dennis obtained a Bachelor of Science degree in mathematics from Mississippi Valley State University and a Master of Science degree in Statistics from Iowa State University.*

Dr. Charles R. (Dick) Lee *is a soil scientist/agronomist in the Environmental Laboratory, Waterways Experiment Station. He leads the Contaminant Assessment and Monitoring Team and provides expertise in environmental chemistry and migration of contaminants in various wetland and upland environments. Dick holds a Bachelor of Science degree in chemistry from the University of Tampa, a Master of Science degree in soil chemistry from Clemson University, and a PhD in agronomy from Clemson University.*



Dr. John W. Simmers *is a research biologist in the Environmental Laboratory, Waterways Experiment Station. He received a Bachelor of Science degree in biology from James Madison University, a Master of Arts degree in Zoology from Miami University, and a PhD in Zoology from Southern Illinois University. John has been involved in developing assessment and management procedures for contaminated upland and wetland ecosystems and is a recipient of the Army Research and Development Achievement Award.*

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This issue provides an update on plant and animal colonization and contaminant mobility observed at upland and wetland sites containing contaminated dredged material at Black Rock Harbor, Connecticut.

ENVIRONMENTAL EFFECTS OF DREDGING

This bulletin is published in accordance with AR 25-30 as an information dissemination function of the Environmental Laboratory of the Waterways Experiment Station. The publication is part of the technology transfer mission of the Dredging Operations Technical Support (DOTS) Program managed by the Environmental Effects of Dredging Programs. Results from ongoing research programs will be presented. Special emphasis will be placed on articles relating to application of research results or technology to specific project needs. Contributions of pertinent information are solicited from all sources and will be considered for publication. The contents of this bulletin are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or the approval of the use of such commercial products. Communciations are welcomed and should be addressed to the Environmental Laboratory, ATTN: Dr. Robert M. Engler, U.S. Army Engineer Waterways Experiment Station (CEWES-EP-D), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call AC 601/634-3624.

ROBERT W. WHALIN, PhD, PE
Director

DEPARTMENT OF THE ARMY
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